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IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In r application of:

Date: January 31, 2000

E. Colgan et al.

Group Art Unit: 2871

Serial No.: 08/999,663

Examiner: J. Dudek

Filed: December 18, 1997

Docket No.: YO994-065XX

For: A REFLECTIVE SPATIAL LIGHT MODULATOR ARRAY

Assistant Commissioner for Patents

Washington, D.C. 20231

I hereby certify that this paper is being facsimile transmitted under Rule CFR 1.61(d) to the U.S. Patent and Frademac Office on the date shown above.

Daniel P. Morris

Reg. No. 32,053

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APR 0 5 2000

AFFIDAVIT UNDER 37 CFR 1.131

TECHNOLOGY CENTER 2800

We, Evan G. Colgan, James M.E. Harper and James L. Speidell declares as follows:

We are co-inventors of the invention of the subject matter of the above-identified patent application. As evidenced by the attached copy of our invention disclosure we conceived and reduced the invention to practice prior to October 3, 1993 the filing date of US patent 5,461,501 to Sato et al. The attached invention disclosure was signed by us and be two witnesses and bears a time stamp of the IBM Yorktown Intellectual property Law Department prior to October 3, 1993. All dates have been obliterated.

The undersigned affiant swears further that all statements made herein of his own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or patent issuing thereon.

By:

Evan G. Colgan

State of New York County of Westchester)ss.:)
to me personally known, and known to	JENNIFER A. SMITH Notary Public, State of New York No. 019M5063001 Qualified in Westchester County Commission Expires July 15, 20 002
By: James M. E. Harper	_
State of New York County of Westchester)ss.:)
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Jenniter a Smith Notary	JENNIFER A. SMITH Notary Public, State of New York No. 01SM5063001 Qualified in Westchester County Commission Expires July 15, 20.000
By: James L. Speidell	-
State of New York County of Westchester)ss.:)
On this 15th day of February to me personally known, and known to	me to be the person described in and who executed the edged to me that he executed the same as his free act and
Jennifer a Smith Notary	JENNIFER A. SMITH Notary Public, State of New York No. 01SM5063001 Qualified in Westchester County Commission Expires July 15, 20

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Critical Dates:

Suggested Evaluator: DEPP HORN

PENTOR, ON INTERNATIONAL ASSIGNMENT. Is any inventor of this disclosure in this country on assignment from another country? YES. DNO. If "Yes", see instruction #5.

SCRIPTION OF INVENTION -

Th Problem

Light-valve arrays are used in projection displays, optical interconnect, optical computing, and other applications in which hight is to be directed in specific directions based on a prescribed function and/or pattern. (We use light-valve array and spatial light modulator symonymously). Four of the factors which affect the performance of the light-valve array are: (i) Optical through-put. This is enhanced by using a reflective array with high aperture ratio and highly reflecting mirrors. High aperture ratio demands that the mirrors are individually large compared to the gaps between them: this requires precise fabrication. High reflectivity requires using a highly reflective metal such as Al or Ag, and fabricating it on a smooth and flat surface. (ii) Light must be kept from interacting with the underlying CMOS circuits; thus an optical barrier must be fabricated preventing the incident light from reaching the CMOS circuits. (iii) If used in the normally black mode the liquid or

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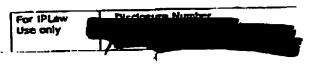
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Page 2 of 4

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artition of invention



ystal cell thickness must be precisely controlled. (iv) If large numbers of mirrors are to be fabricated in a single array, a lithography must be developed which enables the precise fabrication of millions of mirrors over areas larger than the exposure field of step and repeat lithography tools.

The Inv ntion

Figure one shows an embodiment of this invention. The function of the several structures and the processes used to fabricate them are: (1) A silicon water on which CMOS (or other forms of circuits) circuits have been fabricated and on which a passivating insulating layer has been fabricated is the starting point. (2) If needed an additional insulating layer is deposited on that it is possible to polish (chem-mech polish) the wafer flat and smooth and achieve a planarized surface. The insulating layer is for example SiO2. (3) The surface is planarized using chem-mech polishing so that either the M1 metallurgy is exposed at its highest point or so that grouly a thin layer of oxide (about 1000A) covers MI at its highest point. (4) If MI is exposed, a thin oxide layer is deposited (about 1000 A). (5) Using a lift-off or etch process a thin layer of light reflecting and absorbing material is deposited and patterned. An example of thin reflecting and absorbing material would be Cr metal followed by CrO deposited by sputtering. The total thickness would be about 1000A. The pattern is a uniform layer except for holes in the harrier to allow study to make contact to the M1 layer below. (6) An additional layer of SiO2 is deposited or grown (possibly in two layers to eliminate pin holes). The thickness is about 2500 A. (7) Stud holes are patterned and opened in the oxide down to the MI layer at the positions of the holes in the barrier layer. (8) These holes are filled with a flash (about 250 A) of titanium followed by several thousand angstroms of tungsten to fill the stud holes.. (9) Using the Damascene process the surface is polished down to the study exposing them and removing all metal from the surrounding arra. (10) Using a lift-off or etch process a highly reflecting metal is deposited and patterned to form the mirrors. The metal may be Al or Ag for highest reflectivity. (11) The patterning of the metal mirrors is a critical step since the eye is so sensitive to sharp edges in a pattern. Since a large array (with, say, 4 million individual mirrors on a pitch of 15 microns) is larger than the exposure field of any step and repeat lithography tool, stitching between fields with no visible discontinuity is required. Using careful alignment and a GCA stepper, we have shown that stitching alignments of about 0:1 micron can beachieved. This should be adequate for this purpose. This method also enables a gap between mirrors of one micron to be maintained. This is important to maintain a high aperture ratio. (12) An etch stop layer of 500 angstroms of Si3N4 is deposited followed by approximately 2 microns (ie the required liquid crystal cell gap thickness) of SiO2. These materials are deposited at low temperature to avoid roughen ing the mirrors. (13) A photolithography step is used with wet etching (wet

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WITHEREES: The two witnesses whose signs the real and understand this entire invention	ture appear below		DISCLOSURE	SUBMITTED BY	13 000
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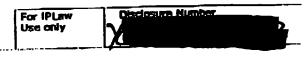
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Pag 3 of 4

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etch can be glycerated BHF) and for reactive ion etching, stopping on the etch stop layer. The photoresist layer is removed and a standard LC cell fabrication process is followed.

The resulting structure then is highly reflecting, high aperture ratio, highly planarized, provides an effective optical barrier for the circuits below, and has a precisely controlled LC cell gap thickness. A uniform aperture ratio of about 85 % is possible with a 15 micron pitch. Such an aperture ratio degrades significantly if the one micron gaps between mirrors cannot

for the circuits below, and has a precisely controlled I.C cell gap thickness. A uniform aperture ratio of about 85 % is possible with a 15 micron pitch. Such an aperture ratio degrades significantly if the one micron gaps between mirrors cannot be maintained. The planarization of the surface should be possible to +/- 500 Λ , effectively increasing the optical contrast and through-put. The reflectivity of Λ 1 is about 92 % and that of Λ 2 is 98 % in the visible giving high optical through-put and contrast. The Cr/Cr0 optical barrier can be designed to have visible reflectivity between 10 and 25 %. The 1 w reflectivity of this layer enhances the contrast ratio. The barrier prevents light from reaching the circuits below in two ways. First, through multiple reflections between the barrier and the bottom side of the mirror, the light can in principle leak down to the circuits. However, since the barrier layer is absorbing the light is attenuated with each reflection. For the small angles of incidence of the input light there will be a very large number of reflections effectively absorbing essentially all of the light. As a worst case estimate, we calculate that the input light must be attenuated by a factor of 100 000. This large factor is achieved with just five reflections if the reflection coefficient is 10 %. In practice a much larger number of reflections occur. For wavelengths of light in the oxide greater than twice the oxide thickness the barrier-oxide-mirror acts as waveguide beyond cut-off. Thus for n = 1.5 and the oxide thickness of 2500 Λ all wavelengths (in air) greater than 7500 Λ will not propagate and are very strongly attenuated. For some circuits the capacitance between the barrier and the mirrors has to be limited. This may place a practical limit on how thin the oxide can be made.

Fabrication of the spacer on the Si has significant advantages in that the spacers can be precisely aligned relative to the mirrors and the height can be controlled with a high degree of accuracy. This latter is important in order to controll the magnitude of the electrooptic effect of the cell so as to achieve a truly black state for the display at all wavelengths of light.

Th Claim

What is claimed here is: (1) A light valve structure which has been fabricated-directly on a Si water. The structure incorporates the control electronics and has been planarized. (2) A light barrier structure which effectively prevents incident light from reaching the underlying Si circuits. (3) A process and method to fabricate a large array of precisely defined highly reflecting mirrors. (4) A liquid crystal cell spacer technology consisting of SiO2 spacers which are fabricated on the light valve and which provide a precisely controlled cell gap thickness.

IMPORTANT: Information provided by this form may be used to prepare a patern application union will be signed by the inventors, inventors should take great case in accurately completing by them and in providing full information concerning prior and. Faise statements or concealment in obtaining a patern will subject applicant to thre and/or imprisonment (18 USC 1601) and may

repardire the validity of the patent.					
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Impl mentation

Structures have been fabricated to demonstrate the efficacy of the lithography method described above. Additional experiments and evaluations are in progress to demonstrate and quantitatively evaluate the rest of the structure and process steps described above.

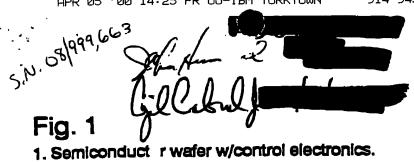
Potential Use

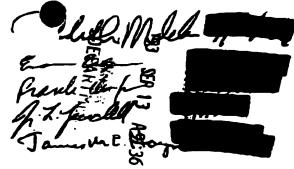
This invention is of potential interest to any company interested in projection displays of any sort. These include projection data monitors (ie Kopin, Tex. Instr., Mitsubishi, and others), projection Television (ie. Philips, Thompson, Projectavision, Hitachi, Toshiba, Sharp, Tex. Instr.,...), conference from projectors (ie Sharp, Philips, Hughes, Greyhawk, GE, Barco,...), retinal projectors (ie Virtual Vision,...). This invention may also find use a spatial light modulator in optical interconnect and optical computing. It may also be used in other applications requiring the direction of light, eg laser printing. The advantages of the present invention over other structures and fabrication methods include optical through-put, contrast and the ability to make large arrays with existing lithography tools. Other methods do not do these as well. A potential competitor to the present invention is the Texas Instruments digital mirror device which is based on a different principal. That device is proprietary to TI and its performance is not fully known by us.

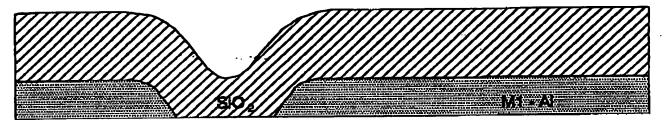
References

- (1) Lueder, SID 93,pg 287.
- (2) Glucck et al. SID 92, pg 277.
- (3) Shikama et al, SID '93, pg 295.
- (4) Glueck et al, SID 93, pg 299.

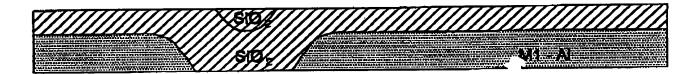
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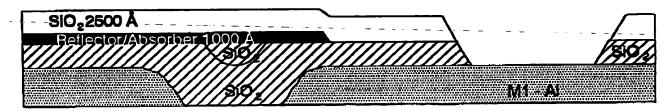
2. Deposit more SiO 2 and Chemical-mechanical polish



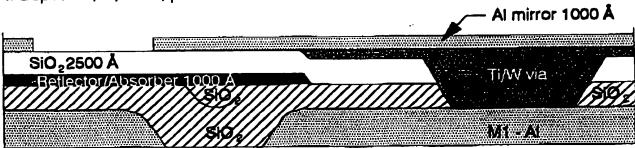
3. Deposit and pattern Reflector/Absorber layer

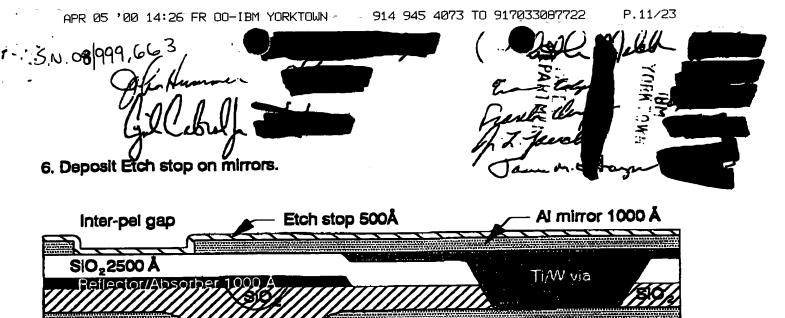


4. Deposit SiO₂, pattern via.

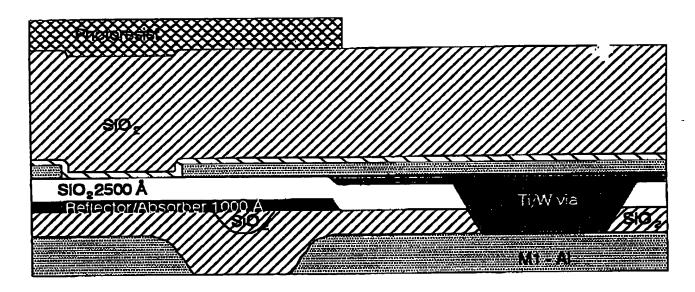


4. Deposit Ti/W, CMP, pattern Al mirror.

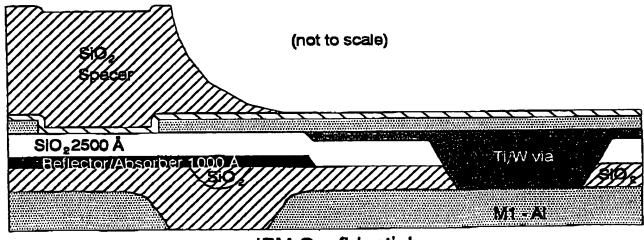




7. Deposit 2 μ m SIO₂ and P.R./expose/develop.



8. Etch SiO₂ in Glycerated buffered HF, ash P.R..



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IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re application of:

Date: February 1, 2000

E. Colgan et al.

Group Art Unit: 2871

Serial No.: 08/999,663

Examiner: J. Dudek

Filed: December 18, 1997

Docket No.: YO994-065XX

For:

A REFLECTIVE SPATIAL LIGHT MODULATOR ARRAY

Assistant Commissioner for Patents Washington, D.C. 20231

CERTIFICATE OF FACSIMILE TRANSMISSION

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Daniel P. Morris Reg. No. 32,053

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LETTER

TECHNOLOGY CENTER 2800

Sir:

Enclosed is a signed Affidavit Under 37 CFR 1.131 corresponding to the unsigned Declaration submitted on January 24, 2000.

Respectfully submitted,

Daniel P. Morris

Reg. No. 32,053

IBM CORPORATION Intellectual Property Law Dept. P.O. Box 218 Yorktown Heights, N.Y. 10598 (914) 945-3217

Date: January 24, 2000

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

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E. Colgan et al.	Group Art Unit: 2871 Decl.
Serial No. 08/999,663	Examiner, J. Dudek Amarsha Parket No. 2 YOSSA 05577 History
Filed: December 18, 1997	Docket No.: YO994-065XX
For: A REFLECTIVE SPATIAL LIGHT N	MODULATOR ARRAY
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hereby certify that this paper is being father U.S. Patent and Trademark Office or	acsimile transmitted under Rule CFR 1.61(d) to Title date shown above.
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DECLARATION	N UNDER 37 CFR 1.131
We, Evan G. Colgan, James M.E. Harper and	d James L. Speidell declares as follows:
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By:	
Evan G. Colgan,	FAX COPY RECEIVED
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The Problem

ESCRIPTION OF INVENTION - Pro

Light-valve arrays are used in projection displays, optical interconnect, optical computing, and other applications in which light is to be directed in specific directions based on a prescribed function and/or pattern. (We use light-valve array and spatial light modulator synonymously). Four of the factors which affect the performance of the light-valve array are: (i) Optical through-put. This is enhanced by using a reflective array with high aperture ratio and highly reflecting mirrors. High aperture ratio demands that the mirrors are individually large compared to the gaps between them: this requires precise fabrication. High reflectivity requires using a highly reflective metal such as Al or Ag, and fabricating it on a smooth and flat surface. (ii) Light must be kept from interacting with the underlying CMOS circuits; thus an optical barrier must be fabricated preventing the incident light from reaching the CMOS circuits. (iii) If used in the normally black mode the liquid or

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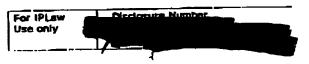
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ystal cell thickness must be precisely controlled. (iv) If large numbers of mirrors are to be fabricated in a single array, a lithography must be developed which enables the precise fabrication of millions of mirrors over areas larger than the exposure field of step and repeat lithography tools.

The invention

Figure one shows an embodiment of this invention. The function of the several structures and the processes used to fabricat them are: (1) A silicon water on which CMOS (or other forms of circuits) circuits have been fabricated and on which a passivating insulating layer has been fabricated is the starting point. (2) If needed an additional insulating layer is deposited so that it is possible to polish (chem-mech polish) the wafer flat and smooth and achieve a planarized surface. The insulating layer is for example SiO2. (3) The surface is planarized using chem-mech polishing so that either the M1 metallurgy is exposed at its highest point or so that youly a thin layer of oxide (about 1000A) covers M1 at its highest point. (4) If M1 is exposed, a thin oxide layer is deposited (about 1000 A). (5) Using a lift-off or etch process a thin layer of light reflecting and absorbing material is deposited and patterned. An example of thin reflecting and absorbing material would be Cr metal followed by CrO deposited by sputtering. The total thickness would be about 1000A. The pattern is a uniform layer except for holes in the harrier to allow study to make contact to the M1 layer below. (6) An additional layer of SiO2 is deposited or grown (possibly in two layers to eliminate pin holes). The thickness is about 2500 A. (7) Stud holes are patterned and opened in the oxide down to the M1 layer at the positions of the holes in the barrier layer. (8) These holes are filled with a flash (about 250 A) of titanium followed by several thousand angstroms of tungsten to fill the stud holes.. (9) Using the Damascene process the surface is polished down to the stude exposing them and removing all metal from the surrounding arm. (10) Using a lift-off or etch process a highly reflecting metal is deposited and patterned to form the mirrors. The metal may be Al or Ag for highest reflectivity. (11) The patterning of the metal mirrors is a critical step since the eye is so sensitive to sharp edges in a pattern. Since a large array (with, say, 4 million individual mirrors on a pitch of 15 microns) is larger than the exposure field of any step and repeat lithography tool, stitching between fields with no visible discontinuity is required. Using careful alignment and a GCA stepper, we have shown that stitching alignments of about 0.1 micron can be achieved. This should be adequate for this purpose. This method also enables a gap between mirrors of one micron to be maintained. This is important to maintain a high aperture ratio. (12) An etch stop layer of 500 angstroms of Si3N4 is deposited followed by approximately 2 microns (ic the required liquid crystal cell gap thickness) of SiO2. These materials are deposited at low temperature to avoid roughen ing the mirrors. (13) A photolithography step is used with wet etching (wet

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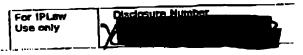
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etch can be glycerated BHF) and for reactive ion etching, stopping on the etch stop layer. The photoresist layer is removed and a standard LC cell fabrication process is followed.

The resulting structure then is highly reflecting, high aperture ratio, highly planarized, provides an effective optical barrier for the circuits below, and has a precisely controlled I.C cell gap thickness. A uniform aperture ratio of about 85 % is possible with a 15 micron pitch. Such an aperture ratio degrades significantly if the one micron gaps between micrors cannot he maintained. The planarization of the surface should be possible to \pm /- 500A, effectively increasing the optical contrast and through-put. The reflectivity of AI is about 92 % and that of Ag is 98 % in the visible giving high optical through-put and contrast. The Cr/Cr() optical harrier can be designed to have visible reflectivity between 10 and 25 %. The 1 w reflectivity of this layer enhances the contrast ratio. The barrier prevents light from reaching the circuits below in two ways. First, through multiple reflections between the barrier and the bottom side of the mirror, the light can in principle leak down to the circuits. However, since the harrier layer is absorbing the light is attenuated with each reflection. For the small angles of incidence of the input light there will be a very large number of reflections effectively absorbing essentially all of the light. As a worst case estimate, we calculate that the input light must be attenuated by a factor of 100 000. This large factor is achieved with just five reflections if the reflection coefficient is 10 %. In practice, a much larger number of reflections occur. For wavelengths of light in the oxide greater than twice the oxide thickness the barrier-oxide-mirror acts as waveguide beyourd cut-off. Thus for n = 1.5 and the oxide thickness of 2500 A all wavelengths (in air) greater than 7500 A will not propagate and are very strongly attenuated. For some circuits the capacitance between the barrier and the mirrors has to be limited. This may place a practical limit on how thin the oxide can be made.

Fabrication of the spacer on the Si has significant advantages in that the spacers can be precisely aligned relative to the mirrors and the height can be controlled with a high degree of accuracy. This latter is important in order to controll the magnitude of the electrooptic effect of the cell so as to achieve a truly black state for the display at all wavelengths of light.

Th Claim

What is claimed here is: (1) A light valve structure which has been fabricated directly on a Si wafer. The structure incorporates the control electronics and has been planarized. (2) A light harrier structure which effectively prevents incident light from reaching the underlying Si circuits. (3) A process and method to fabricate a large array of precisely defined highly reflecting mirrors. (4) A liquid crystal cell spacer technology consisting of SiO2 spacers which are fabricated on the light valve structure and which provide a precisely controlled cell gap thickness.

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impl mentation

Structures have been fabricated to demonstrate the efficacy of the lithography method described above. Additional experiments and evaluations are in progress to demonstrate and quantitatively evaluate the rest of the structure and process steps described above.

P t ntial Use

This invention is of potential interest to any company interested in projection displays of any sort. These include projection data monitors (ie Kopin, Tex. Instr., Mitsubishi, and others), projection Television (ie. Philips, Thompson, Projectavision, Ilitachi, Toshiba, Sharp, Tex. Instr.,...), conference room projectors (ie Sharp, Philips, Hughes, Greyhawk, GE, Barco,...), retinal projectors (ie Virtual Vision,...). This invention may also find use a spatial light modulator in optical interconnect and optical computing. It may also be used in other applications requiring the direction of light, eg laser printing. The advantages of the present invention over other structures and fabrication methods include optical through-put, contrast and the ability to make large arrays with existing lithography tools. Other methods do not do these as well. A potential competitor to the present invention is the Texas Instruments digital mirror device which is based on a different principal. That device is proprietary to TI and its performance is not fully known by us.

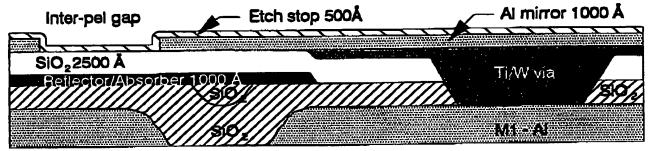
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- (1) Lueder, SID 93,pg 287.
- (2) Glucck et al. SID 92, pg 277.
- (3) Shikama et al, SID '93, pg 295.
- (4) Glucck et al, SID 93, pg 299.

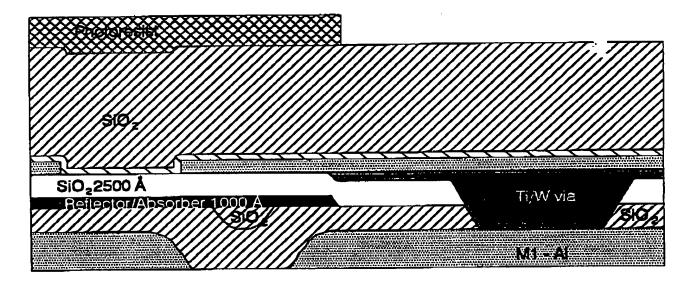
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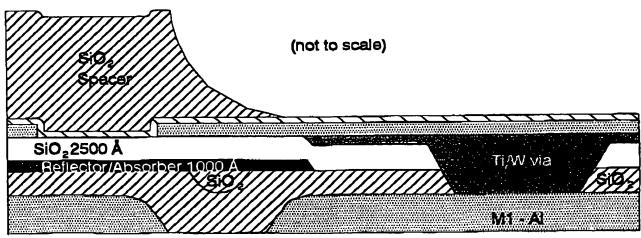
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7. Deposit $2 \mu m SiO_z$ and P.R./expose/develop.



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